GLIDING SUBMERSIBLE TRANSPORT SYSTEM

INVENTOR
Henry August

FIELD OF THE INVENTION

The present invention relates generally to submersible vehicles and, more specifically, to submersible gliders.

BACKGROUND OF THE INVENTION

Marine vessels have long been used for commercial and military purposes. For example, commercial ships transport goods and tourists. As another example, military surface ships project power and deliver ordnance to targets, deliver military supplies and logistics, and transport military personnel. Further, military submarines deliver ordnance to targets and provide strategic deterrence from stealthy platforms. Finally, civilian and military marine vessels engage in scientific research of the ocean environment.

In some applications, it would be desirable to accomplish some of the objectives listed above through use of unmanned marine vessels. For example, use of an unmanned marine vessel to deliver ordnance, such as a torpedo, to a target would permit the ordnance to be delivered to the target without putting sailors in harm's way. However, currently known unmanned delivery vehicles produce large amounts of noise. As a result, currently known delivery vehicles may not bring significant amounts of stealth to a tactical situation. Thus, a target may gain a tactical advantage. Accordingly, effectiveness of currently known delivery vehicles may be diminished.

In order to maximize Mission effectiveness of unmanned marine vessels, it would be desirable to increase the amount of stealth enjoyed by the unmanned marine vehicle.

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Seattle, Washington 98104
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Currently known submersible gliders, such as the Seaglider, can be considered stealthy submersible vehicles. The submersible gliders have high aspect ratio wings that impart a forward gliding to the glider as the glider experiences changes in ballast and their resultant changes in buoyancy.

Currently known underwater gliders can propel themselves for an extended period of time by modulating buoyancy through controlled ballasting. That is, gliders trade potential energy into work against drag. An underwater glider that is designed to be nearly-neutrally buoyant at the surface sinks very slowly. Therefore, the glider can attain extended range via its high lift-to-drag ratio that is largely achieved by its lifting surface. Once the glider attains its desired depth, internal air volume of the glider is increased, thereby lowering its density. This increases buoyancy force above weight of the glider, and the glider buoys upward to the surface of the sea. This phenomenon of using buoyancy to energize an underwater glider functions until ballasts are exhausted. That is, underwater gliding refers to motion in which the force of gravity provides propulsion, while steering is maintained typically by controlling location of the center of gravity of the vehicle.

Many currently known underwater gliders are used for oceanographic research, meteorology research, and deep-sea surveying. These currently known gliders used fixed wings for glide and pitch control and internal ballasts for depth and altitude control. For example, the "Slocum" glider uses ballast tanks to provide pitching moment's joint upward and downward glides and a sliding battery mass for fine adjustment of pitch and roll. With an operational range of 40,000 km, Slocum obtained its propulsive energy from thermal gradients in the water using a thermal engine that draws energy from ocean thermal clients (that is, temperature differences between warm surface water and cooler, deep water). Another currently known glider, "Spray," has a range of 6000 km and has been developed and demonstrated under similar gliding principles to the Slocum. Apart from saving energy for propulsion, Spray lasts longer and operates more quietly than Slocum because of a lack of moving surfaces.

However, currently known gliders have limited glider range and applicability. For example, the Seaglider can attain speeds up to 0.5 knots at glide angles from 8° to 70° (1:5-3:1 slope). Because of the Seaglider's limited speed and glide capabilities, the Seaglider is limited to oceanographic research.

It would be desirable for an unmanned marine vehicle to provide for delivery of ordnance, supplies, personnel, or the like. However, internal capacities of currently known gliders are limited due to extensive components for ballasting and steering. Therefore, there

is an unmet need in the art for an unmanned submersible transport system that provides desired stealth, speed, and other performance characteristics.

SUMMARY OF THE INVENTION

Embodiments of the present invention provide a gliding submersible transport system. Exemplary embodiments provide submersible gliders having wings capable of providing sufficiently high lift-to-drag ratios such that the submersible gliders of the present invention may be used for transporting large volumes of military or commercial hardware, equipment, personnel, or the like.

According to one exemplary embodiment of the present invention, a submersible glider has a step-wise glider range. The glider includes a substantially cylindrical hull having a bow and a stern. A generally planar lifting surface is disposed toward the stern. The lifting surface has a pair of generally planar stabilizer surfaces that extend generally perpendicular to a plane of the lifting surface from ends of the lifting surface. A nose cone and at least one steering device are disposed toward the bow.

According to an aspect of this embodiment of the present invention, the lifting surface is an "arch wing" with a box plane-like design that provides a higher effective aspect ratio than a planar wing with a comparable planform. As a result, higher lift and greater hydrodynamic efficiency (that is, to lift-to-drag ratio) are generated than in a corresponding planar wing. Extended stepwise glide ranges result from use of the arch-wing. The submersible glider gradually buoys to the surface under controlled ballasting and repeatedly glides forward along a glide path slope determined by the lift-to-drag ratio. Advantageously, the submersible glider of this embodiment of the present invention may slowly and quietly transport heavy payloads including special supplies, sensor platforms, ordnance, and heavy equipment as desired, such as an unmanned aerial vehicle (UAV).

According to another embodiment of the present invention, a marine transport system is provided. The transport system includes a submersible glider having a step-wise glider range, such as described above. A surfaced glider has a towing mechanism configured to reel in and reel out from the surfaced glider a tow line that is connectable to the submersible glider.

According to an aspect of this embodiment of the present invention, a surfaced glider defines a hold that may be configured as a personnel cabin for surfaced transport of personnel. Advantageously, the personnel are housed in the surfaced glider that is designed to float and travel along the sea surface. The surfaced glider may be "self-towed" forward to the submersible glider after the submersible glider buoys to the surface. As a result, personnel may be transported in a relatively safe and stealthy manner. Use of the surfaced

glider to transport personnel avoids risks and extreme costs incurred with transport of personnel in a submerged glider. Advantageously, use of the surfaced glider avoids complex underwater life-support and emergency escape systems for submerged transport of personnel.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred and alternative embodiments of the present invention are described in detail below with reference to the following drawings.

FIGURE 1 is a perspective view of a submersible glider according to an embodiment of the present invention;

FIGURE 2 is a side plan view of a glider according to another embodiment of the present invention;

FIGURE 3 illustrates an exemplary marine transport system incorporating the gliders of FIGURES 1 and 2;

FIGURES 4A-4E illustrate details of a wing of the glider of FIGURE 1;

FIGURES 5A and 5B illustrate details of a steering device of the glider of FIGURE 1;

FIGURES 6A-6H illustrate details of control surfaces of the glider of FIGURE 1;

FIGURE 7 illustrates details of a tail cone of the glider of FIGURE 1;

FIGURE 8 is an exploded perspective view of alternate components of the glider of FIGURE 1;

FIGURE 9 is an end view of an exemplary propeller of the gliders of FIGURES 1 and 2;

FIGURE 10 is a graph of step-wise glider range for the glider of FIGURE 1;

FIGURE 11 is a graph of lift coefficient versus angle of attack for the glider of FIGURE 1;

FIGURE 12 is a graph of lift-to-drag ratio versus angle of attack for the glider of FIGURE 1;

FIGURE 13 is a graph of lift coefficient versus pitching moment coefficient for the glider of FIGURE 1;

FIGURE 14 is a graph of yawing moment versus angle of sideslip for the glider of FIGURE 1;

FIGURE 15 is a graph of incremental yawing moment coefficient per deflection versus angle of sideslip for the glider of FIGURE 1;

FIGURE 16 is a perspective view of the glider of FIGURE 1 outfitted with external stores;

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FIGURE 17A illustrates a scenario of an exemplary mission performed by the glider of FIGURE 16;

FIGURE 17B illustrates details of a portion of the mission of FIGURE 17A;

FIGURE 17C illustrates a scenario of another exemplary mission performed by the glider of FIGURE 16;

FIGURES 18A and 18B illustrate transport and launch of an unmanned aerial vehicle from the glider of FIGURE 1;

FIGURE 19 illustrates transport and launch of the glider of FIGURE 1 from a submerged submarine;

FIGURES 20A and 20B are plan views of the glider of FIGURE 2 when surfaced; and

FIGURES 21A and 21B are plan views of the glider of FIGURE 2 when submerged.

DETAILED DESCRIPTION OF THE INVENTION

By way of overview, embodiments of the present invention provide a gliding submersible transport system. Exemplary embodiments provide submersible gliders having wings capable of providing sufficiently high lift-to-drag ratios such that the submersible gliders of the present invention may be used for transporting large volumes of military or commercial hardware, equipment, personnel, or the like. According to one exemplary embodiment of the present invention, a submersible glider has a step-wise glider range. The glider includes a substantially cylindrical hull having a bow and a stern. A generally planar lifting surface is disposed toward the stern. The lifting surface has a pair of generally planar stabilizer surfaces that extend generally perpendicular to a plane of the lifting surface from ends of the lifting surface. A nose cone and at least one steering device are disposed toward the bow. According to another embodiment of the present invention, a marine transport system is provided. The transport system includes a submersible glider having a step-wise glider range, such as described above. A surfaced glider has a towing mechanism configured to reel in and reel out from the surfaced glider a tow line that is connectable to the submersible glider.

Exemplary embodiments of submersible and surfaced gliders will be briefly introduced, followed by details of their construction and operation. In addition, exemplary scenarios of missions that may be performed by embodiments of the present invention will be explained.

Referring briefly to FIGURE 1 and given by way of nonlimiting example, a submersible glider 10 according to one exemplary embodiment of the present invention has a step-wise glider range (described below with reference to FIGURE 10). The glider 10

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includes a substantially cylindrical hull 12 having a bow 14 and a stern 16. A generally planar lifting surface 18 is disposed toward the stern 16. The lifting surface 18 has a pair of generally planar stabilizer surfaces 20 that extend generally perpendicular to a plane of the lifting surface 18 from ends of the lifting surface 18. A nose cone 22 and at least one steering device 24 are disposed toward the bow 14.

Referring briefly now to FIGURE 2 and given by way of nonlimiting example, a surfaced and submersible glider 30 according to another exemplary embodiment of the present invention includes a wave-piercing hull 32 having a bow 34 and a stern 36. A generally planar surface 38 is substantially disposed toward the stern 36. The generally planar surface 38 has a pair of generally planar stabilizer surfaces 40 that extend generally perpendicular to a plane of the generally planar surface 38 from ends of the generally planar surface 18. A pair of lifting skis 42 suitably may be disposed on the pair of stabilizer surfaces 40 for emergency power. A towing mechanism 44 is mounted to the hull 32 and is configured to reel in and reel out to and from the glider 30 a tow line 46. A hold 48 may be configured as a personnel cabin for surfaced transport of personnel.

Referring now to FIGURE 3, a marine transport system 50 includes the submersible glider 10 and the surfaced glider 30. The tow line 46 is connected to the submersible glider 10. Advantageously, personnel are housed in the cabin 48 of the surfaced glider 30 that is designed to float and travel along a surface 52 of the sea. The surfaced glider 30 is "self-towed" forward to the submersible glider 10 after the submersible glider 10 buoys to the surface. Specifically, as the submerged glider 10 descends from the surface 52, the glider 10 travels forward along a glide path 54. During descent of the glider 10, the tow line 46 is reeled out from the surfaced glider 30 by the towing mechanism (FIGURE 2). This reeling out of the tow line prevents the surfaced glider 30 from being pulled under the surface 52 by the glider 10 as the glider 10 descends. While the glider 10 buoys to the surface 52 under controlled ballasting, or alternately after the glider 10 has surfaced, the towing mechanism 44 (FIGURE 2) reels in the tow line 46. This reeling in of the tow line 46 imparts a forward motion indicated by an arrow 54. The descent, reeling out, ascent, reeling in, and forward motion cycle is repeated as desired for a particular scenario, mission, application, or the like. As a result, personnel may be transported in a relatively safe, stealthy, and low cost manner. It will be appreciated that use of the surfaced glider 30 to transport personnel avoids risks and extreme costs incurred with transport of personnel in a submerged glider. Advantageously, use of the surfaced glider 30 avoids complex underwater life-support and emergency escape systems for submerged transport of personnel. In addition, this dual vehicle approach

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Seattle, Washington 98104
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maximizes the use of internal volume of the submerged glider 10 for the transport of equipment and goods.

Now that embodiments of the submerged glider 10 and the surfaced glider 30 and an embodiment of the marine transport system 50 that incorporates the gliders 10 and 30 have been briefly introduced, details of their construction, operation, and use will now be explained.

Referring now to FIGURES 4A-4E, to the glider 10 advantageously incorporates an "arch wing" design for the lifting surface 18. The arch wing has a boxplane-like design including end plates, which are the stabilizer surfaces 20 that provide a higher effective aspect ratio than a planar wing with a comparable planform. In addition to the outboard stabilizer surfaces 20, the lifting surface 18 includes an upper wing panel 60 and a lower wing panel 62. The upper and lower wing panels 60 and 62 are highly swept. The stabilizer surfaces 20 extend substantially normally, that is substantially perpendicularly, between the upper and lower wing panels 60 and 62. In one exemplary embodiment, hydrodynamic control surfaces such as elevons 64 are provided at a trailing edge 66 of the lower wing panel 62.

Advantageously, the arch wing design of the lifting surface 18 imparts to the glider 10 an efficient glide ratio, that is horizontal distance traversed over vertical distance descended in a given time interval. As a result, the glider 10 achieves a useful combination of glider range and diving depth. That is, the glider 10 yields high hydrodynamically lift-to-drag ratios so as to maximize its step-wise glide range. The lifting surface 18 yields high lift-to-drag with minimum noise disturbances in the fluid flow. As a result, the high-aspect ratio planar wings of the lifting surface 18 yield extended glide slopes, longer glide ranges, stability in pitch, yaw, and roll, and greater maneuverability for maintaining desired flight directions and pathways against countering sea currents. In addition, the arch wing design of the lifting surface 18 provides a stronger structural truss in lift than does a planar wing of conventional planform.

The arch wing design of the lifting surface 18 yields a favorable hydrodynamic "end-plate wing" effects. These effects induce a higher effective aspect ratio then either of the upper or lower wing panels 60 and 62. As result, wing tip losses are reduced. Correspondingly, the drag-due-to-lift of the arch wing is reduced and hydrodynamic efficiency (that is, lift-to-drag ratio) is increased. Because the highly swept lifting surface 18 is located aft, that is toward the stern 16, the stabilizer surfaces 20 act as pseudo-twin vertical stabilizers. Further, the lifting surface 18 enjoys added lift and greater stability by a captured "bent streamtube" process, which at incidence, reacts to downward turning of the captured

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Seattle, Washington 98104
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streamtube. This contribution to lift is similar to that provided by the inlet of a jet power aircraft at incidence.

Advantageously, the elevons 64 provide control surfaces for pitch and roll. Consequently, the glider 10 need not employ a conventional traversing inner weight device for varying location of center of gravity of the glider 10. Use of the elevons 64 instead of conventional traversing inner weight devices provides a significant advantage of preserving inner volume of the glider 10 such that transportation of equipment and payloads can be maximized.

High strength airbags (not shown) are positioned externally on sides of the hull 12 and within outer regions between the upper and lower wing panels 60 and 62. The airbags may be made of a high-strength, light-weight material such as Mylar®. To preserve internal volume of the hull 12 for the transporting of equipment, on-board ballasting is done by gaseous inflation, such as by an inert gas like nitrogen, of the externally mounted airbags. The glider 10 is nearly-neutrally buoyant at the surface and can slowly and stealthily sink along a shallow glide path, thereby achieving extended ranges via a high lift-to-drag ratio. Upon the glider 10 reaching desired depth, the airbags are inflated using the on-board ballasts. This lowers overall density of the glider 10 and largely increases buoyancy of the glider 10, thereby driving the glider 10 toward the surface of the sea. This approach of external ballasting also accommodates extra heavy payloads by use of more airbags, larger airbags, or both more and larger airbags.

Referring now to FIGURES 1, 4B, and 4E, the steering devices 24 are forward-mounted, lateral control surfaces. The steering device is 24 are side-mounted, low-drag conformal steering devices that are deflected outboard (left or right hand). Advantageously and in addition, the steering devices 24 can be used with symmetric deflections as aids for achieving trim in pitch (producing nose-up moment contributions as needed).

Referring now to FIGURES 5A and 5B, the steering devices 24 increase control effectiveness and reduce heat load. Outboard, stilt-like panels 68 are mounted to and rotate trailing edge outward from the hull 12. A deflection surface 70 is mounted to the panels 68 such that the leading edge of the deflected surface 70 is spaced apart from the hull 12. As a result, a boundary layer of fluid, indicated by an arrow and 72, flows between the deflection surface 70 and the hull 12. That is, the panels 68 provide a kept, stand-off region that allows boundary layer flow to propagate therethrough. As the boundary layer flow propagates through the panels 68 and above and under an outer deflection surface 71 as indicated by the arrow 72, a hydrodynamic lateral force, indicated by an arrow 74, is generated at the forward region of the glider's hull 12. A steering deflection angle δ results. Actuators (not shown)

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for rotation of the stilt-like panels 68 and deflection surface 70 suitably are housed within the glider's hull 12 just forward of the steering devices 24. The actuators may be any suitable electromechanically driven devices.

Referring now to FIGURES 6A-H, optional ring canards may be provided, if desired, for additional or independent pitch and yaw control. As shown in FIGURE 6A, a canard 76 has variable incidence as indicated by an arrow 78. The canard 76 has substantially no twist applied to it. As shown in FIGURES 6B and 6C, a canard 80 has a countertwist of +/-10° applied to it by rotation of the hull's opposing side-supports (electromechanically driven from within) such that the canard 76 asymmetrically distorts its shape and thereby skews itself to a sideslip angle $\beta = -5°$ relative to the hull 12. A canard 82 has an opposite counter-twist of -/+10° applied to it such that the canard 76 skews to a sideslip angle $\beta = +5°$ relative to the hull 12. In this manner, lateral forces are generated at the forward hull for steering. Referring now to FIGURE 6D, any of the canards 76, 80, or 82 provide pitch control about a center of gravity of the glider 10 as indicated by angle of attack α. Incidence toward a forward portion of the arrow 76 results in a download 84. Incidence further along the arrow 76 results in an upload 86.

Referring to FIGURES 6E and 6F, the canard 76 with no applied twist generates zero lateral control forces. Referring to FIGURE 6G, the canard 82 generates nose right lateral control forces. Referring to FIGURE 6H, the canard 80 generates nose left lateral control forces.

Referring now to FIGURE 7, a conical afterbody section, such as a tail cone 88, is provided toward the stern 16 of the glider 10. Advantageously, the tail cone 88 reduces base drag of the glider 10, thereby aiding gliding efficiency. In one exemplary embodiment, the tail cone 88 is inflatable. The tail cone 88 suitably is stored within the stern 16, and is deployed and inflated during its approach and landing phase. 10. The tailcone 88 is rapidly inflated by a gas, such as an inert gas like nitrogen gas, that is released into it from a pressurized container (not shown) stored within the stern 16. A valve (not shown) preset to open at a selected pressure, altitude or depth, or a time of flight device (not shown) can be used to initiate the pressurized gas flow.

Referring now to FIGURE 8, in one presently preferred embodiment the nose cone 22 is "bent." That is, the nose cone 22 has an axis this is not collinear with an axis of the hull 12. Advantageously and as a result, the nose cone 22 functions as a preset lifting component for achieving self-trim in pitch. In one exemplary embodiment, the nose cone 22 is bent by around 5 degrees or so. In other embodiments, a nose cone 22a is bent by around ten degrees or so. However, in other embodiments, a nose cone 22b is not bent or has substantially no

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bend. While some amount of "bend" to the nose cone is desirable and is presently preferred to aid in pitch control, it will be appreciated that any amount of "bend" may be provided as desired, if any bend is provided at all.

Still referring to FIGURE 8, several variations may be provided to components of the glider 10. Given by way of nonlimiting example, steering devices 24a, 24b, and 24c suitable have deflections of around zero degrees, ten degrees, and twenty degrees, respectively. Given by way of further nonlimiting examples, steering devices 24d and 24e have incidences of around minus ten degrees and minus twenty degrees, respectively. However, it will be appreciated that any steering device may have any deflection or incidence as desired for a particular application.

Still referring to FIGURE 8, optional vertical stabilizers 90 may be provided as needed for further enhancement of the vehicle's lateral stability. The optional vertical stabilizers 90 are optionally provided in addition to the stabilizers 20. If provided, the optional vertical stabilizers 90 are attached to the outboard regions of the upper wing panel 60.

Referring now to FIGURE 9, a propeller 92, such as without limitation a ring propeller, may be provided if desired for higher speed operations. Referring additionally to FIGURES 1 and 2, the propeller 92 may be included with the glider 10 as part of a propulsion system (not shown), such as jet skis. The propeller 92 may be included with the glider 30 as part of the jet skis 42. Advantageously, the jet skis 42 and the propeller 92 provide the gliders 10 and 30 with emergency propulsion power that enables the gliders 10 and 30 to clear datum and egress from serious threats or from situations in which tactical advantage has been lost. Ring propellers are well known in the art. As a result, details of their construction and operation are not necessary for an understanding of the present invention.

Referring now to FIGURE 10, step-wise glider range of the glider 10 is graph as a function of depth d versus range r. As is known, the ratio of range r to depth r equals lift-to-drag ratio. That is,

$$r/d = L/D \tag{1}$$

As is also known,

$$\gamma = \mathrm{Tan}^{-1}(D/L) = \mathrm{Tan}^{-1}(d/r) \tag{2}$$

Accordingly, application of equations (one) and (two) yields a glide path 94. Referring to Table 1, the range r varies from a range of 500 ft. (at a depth of 100 ft.) for a lift-to-drag ratio of 5 to a range or of 800 ft. (at a depth of 100 ft.) for a lift-to-drag ratio of 8.

Table 1

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L/D (max)	γ (deg)	r/d	glider range r (ft.) (@d=100ft.)
5	11.3	5	500
6	9.5	6	600
7	8.1	7	700
8	7.1	8	800

Referring now to FIGURES 11-15, test data was taken in a low speed wind tunnel (Mach number of 0.15) using a model of the glider 10 with upper and lower wing panels 60 and 62 swept at 35° and 45°. For comparison purposes, data was also taken of models of glider with conventional wing panels swept at 35° and 45° and an aft centerline vertical and trailing rudder (instead of the arch wing design of the lifting surface 18 and the conformal steering devices 24).

FIGURE 11 illustrates lift enhancement of the glider 10. Lift coefficient C_L was graphed versus angle of attack α. A 50% increase was measured in slope of lift curves 96 for the glider 10 over lift curves 98 four the conventional gliders. In addition, a gentle stall was noted to occur above 20° angle of attack.

FIGURE 12 illustrates increased glider range of the glider 10. Lift-to-drag ratio L/D was graphed versus angle of attack α. Curves 100 taken for the glider 10 show a 20% higher maximum lift-to-drag ratio (L/D_{max}) then a maximum lift-to-drag ratio(L/D_{max}) of curves 102 four the conventional gliders. Advantageously and as a result, this 20% increase in maximum lift-to-drag ratio (L/D_{max}) results in a 20% increase in glide range enjoyed by the glider 10 over conventional gliders (*see* Equations (1) and (2)).

FIGURE 11 illustrates higher stability in pitch. Lift coefficient C_L was graphed versus pitching moment coefficient C_m. Curves 104 for the glider 10 show increased lift acting aft of center of gravity of the glider 10 than curves 106 show for conventional gliders. Advantageously and as a result, this imparts in increased stability in pitch to the glider 10.

FIGURE 14 illustrates higher stability in sideslip. Yawing moment C_n was graphed versus angle of sideslip β. Curves 108 for the glider 10 show a higher stability in sideslip over curves 110 for conventional gliders due to the stabilizer surfaces 20 acting as twin, outboard vertical stabilizers.

FIGURE 15 illustrates effectiveness of the conformal steering devices 24 in generating yawing moments. Incremental yawing moment coefficient per deflection δ was graphed versus angle of sideslip β four and angle of attack α of 16°. Curves 112 for the glider 10 and curves 114 for conventional gliders highlight increased effectiveness of the steering devices 24 in generating yawing moments due to their deflection increases with increasing angles of attack. Test data taken at high angle of attack and with 20° deflection of

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the left-hand side panel on the forebody exhibits significant yawing moment control over a sideslip range of +/-10°.

Referring now to FIGURES 16 and 17A-C, the glider???? 10 has been outfitted to carry external stores 116, such as torpedoes. Preferably, the torpedoes 116 are lightweight and compact torpedoes with advanced warheads. Given by way of nonlimiting example, in one presently preferred embodiment, the torpedoes 116 may include a ring wing 118 and advanced warheads, such as HYDRASHOCK warheads. Details regarding the ring wing 118 are set forth in "Ring Wing for an Underwater Missile," AIAA 1993-3651, by H. August and E. Carapezza, the contents of which are hereby incorporated by reference. Details regarding the HYDRASHOCK warhead are set forth in US Pat. number 5,078,069 entitled "Warhead", issued January 7, 1992, the contents of which are hereby incorporated by reference. Further, the glider 10 may be outfitted with electronic systems, such as a sonar system and a fire control system (not shown), that are housed within the hull 12.

As shown in FIGURES 17A and 17B, the glider 10 outfitted with the torpedoes 116, sonar, and fire control systems, advantageously is suited for performing missions such as homeland defense scenarios. In FIGURE 17A, the glider 10 patrols submerged on guard at a station 120 by gliding along its glide path and buoying toward the sea surface. When the glider 10 is alerted by underwater sonar 128 to presence of enemy ships 122, 124, and 126, the glider 10 buoys to the surface and closes range to engage the enemy ship 122. The glider 10 engages the enemy ship 122 with a torpedo 116. In FIGURE 17B, the glider 10 has submerged to engage the enemy ships 124 and 126 with torpedoes 116. The glider 10 increases its stealth and maintains tactical advantage over the enemy ships 124 and 126 by gliding along its glide range. The glider 10 engages the enemy ships 124 and 126 with torpedoes 116. If the enemy ship 126 attempts to engage the glider 10 with a torpedo 130, then the glider 10 engages the torpedo 130 with a torpedo 116.

In addition to being well-suited for blue water, open ocean operations, the glider 10 is also well-suited for littoral warfare operations. In FIGURE 17C, the glider 10 operates in an offshore submerged patrol area 132. The glider 10 submerges in a littoral operation area 134 and engages an enemy ship 136 with torpedoes 116. In addition, the glider 10 engages a plurality of mines 138 with torpedoes 116.

Referring now to FIGURES 18A and 18B, the glider 10 advantageously is well-suited for carrying an internal store, such as an unmanned aerial vehicle (UAV) 140, in a hold 142 that is defined within the hull 12. The UAV 140 is releasably mounted to an underside of a hatch 144 that is part of the upper wing panel 60. Wings 146 of the UAV 140 are stored longitudinally aligned with an axis of the UAV 140 and the glider 10. The hatch 144 is

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rotated as indicated by an arrow 148, thereby positioning the UAV 140 outside of the hull 12 and aligned along its outside of the hull 12 for takeoff. The wings 146 are rotated in position for flight, and the UAV 140 takes off from the glider 10.

Referring now to FIGURE 19, the glider 10 suitably is transported to operation areas (not shown) by a submerged submarine 150. The glider 10 is attached to an exterior of the submarine 150 with a suitable carriage 152. The carriage 152 releasably attaches the glider 10 to the submarine 150. The releasable attachment may be accomplished by any acceptable attachment method. For example, the carriage 152 may include mechanical latches, hooks, or the like to releasably attach the glider 10 to the submarine 150 and launch the glider 10 for operations. Alternately, the carriage 152 may use magnets, electromagnets, air bags, or the like to attach and launch the glider 10.

Referring now to FIGURES 20A-B and 21A-B, it will be appreciated that the glider 30 is also well-suited for blue water, open ocean missions as well as close-in, littoral missions. Referring first to Figure 20A, a plurality of the torpedoes 116 may be mounted on the planar surface 38. The glider 30 is surfaced, and the glider 30 is supported on the surface of the water by the wave-piercing hull 32 and the lifting skis 42. As such, the glider 30 when surfaced has a catamaran configuration. That is, the planar surface 38 is spaced above the surface of the water. Referring briefly to FIGURE 20B, it will be appreciated that, looking down, in one embodiment the glider 30 has an appearance of a manta ray.

Referring now to FIGURES 21A and 21B, the glider 30 is submerged. Because the glider 30 is submerged, it will be appreciated that the glider 30 has negative buoyancy or neutral buoyancy. In the submerged configuration, the wave-piercing hull 32 is interposed between the surface of the water and the planar surface 38. That is, the glider 30 is inverted compared to the configuration of the glider 30 as shown in FIGURE 20A.

It will be appreciated that the glider 30 may also include electronics systems, such as sonar and fire control systems, the torpedoes 116, and the lifting skis 42 including the propellers 92 similar to the glider 10. With inclusion of such features, the glider 30 is similarly suitable for performing the missions described above for the glider 10.

While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.

BLACK LOWE & GRAHAM PLLC
701 Fifth Avenue, Suite 4800
Seattle, Washington 98104
206.381.3300 • F: 206.381.3301